13:36:25 OCA PAD INITIATION - PROJECT HEADER INFORMATION 10/07/88

Active

Project #: E-16-696 Cost share #: E-16-334 Rev #: 0
Center # : R6602-0A0 Center shr #: F6602-0A0 OCA file #:
Work type : RES
Contract#: DAAL03-88-G-0070 Mod #: Document : GRANT
Prime #: Contract entity: GTRC

Subprojects ? : N
Main project #:

Project unit: AE Unit code: 02.010.110
Project director(s):
KOMERATH N M AE
JAGODA J I AE

Sponsor/division names: ARMY / ARO, RES TRIANGLE PARK, NC
Sponsor/division codes: 102 / 001

Award period: 881001 to 890930 (performance) 891130 (reports)

Sponsor amount	New this change	Total to date
Contract value	73,575.00	73,575.00
Funded	73,575.00	73,575.00
Cost sharing amount		24,525.00

Does subcontracting plan apply ?: N

Title: COPPER VAPOR PULSED LASER SYSTEM FOR PLANAR DIAGNOSTICS

PROJECT ADMINISTRATION DATA

OCA contact: Ina R. Lashley 894-4820

Sponsor technical contact

(000)000-0000

Sponsor issuing office

LARRY E TRAVIS, GRANT OFFICER
(919)549-0641
ARMY RESEARCH OFFICE
P O BOX 12211
RESEARCH TRIANGLE PARK NC 27709-2211

Security class (U,C,S,TS) : U
Defense priority rating : N/A
Equipment title vests with: Sponsor
PER PARA. 8.C (P. 3)

ONR resident rep. is ACO (Y/N): Y
N/A supplemental sheet
GIT X

Administrative comments -
INITIATION OF EQUIPMENT GRANT. ARO WILL PAY MAXIMUM OF 75% OF TOTAL PROJECT COST UP TO $73,575 (SEE PARA 4, P.2). SEE PARA. 8.b, p. 3 RE: SUBSTITUTIONS

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 11/29/89
Original Closeout Started ********

Project No. E-16-696 | Center No. R6602-0A0

Project Director KOMERATH N M | School/Lab AE

Sponsor ARMY/ARO, RES TRIANGLE PARK, NC

Contract/Grant No. DAAL03-88-G-0070 | Contract Entity GTRC

Prime Contract No.

Title COPPER VAPOR PULSED LASER SYSTEM FOR PLANAR DIAGNOSTICS

Effective Completion Date 890930 (Performance) 891130 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	Y	
Government Property Inventory & Related Certificate	Y	
Classified Material Certificate	N	
Release and Assignment	Y	
Other	N	

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
OCA/CSD	N
Other	N
	N

NOTE: Final Questionnaire sent to PDPI.

FINAL REPORT
GITAER 89-2

COPPER VAPOR PULSED LASER SYSTEM FOR PLANAR DIAGNOSTICS

Prepared by:

Dr. Narayanan M. Komerath

School of Aerospace Engineering
Georgia Institute of Technology

Prepared for:

U.S. Army Research Office
Research Triangle Park, N. C.

Under Contract No.

DAAL03-88-G-0070

Report period covered October 1, 1988 to September 30, 1989.

November 1989

GEORGIA INSTITUTE OF TECHNOLOGY

A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF AEROSPACE ENGINEERING
ATLANTA, GEORGIA 30332

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17. COSATI CODES			18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
FIELD	GROUP	SUB-GROUP	Flow Visualization; Metal lasers; vortex flows Copper vapor laser.

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This contract, awarded under the Defense University Research Instrumentation program, funded the purchase and installation of a Copper Vapor Pulsed Laser system, to be used for research on planar diagnostic techniques. The laser system has been installed, and meets its performance specifications and expectations. It has seen several months of regular use, on two A.R.O.- funded research projects. Substantial progress has been made in research on planar diagnostic techniques, and on visualizing the flowfield around a swept rotor blade tip in hover. The high intensity of the laser enables the visualization of detailed, unsteady flow phenomena that were previously inaccessible. Separation of the light into the two dominant wavelengths (510 and 578 nm) enables simultaneous visualization of orthogonal cross-sections of flowfields. Combined with high-speed imaging and digital image processing, this laser system opens up new avenues of progress in fluid dynamics research. Four Conference abstracts and one invention disclosure have been submitted based partially on research performed using this system.

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FINAL REPORT

NARAYANAN M. KOMERATH

NOVEMBER 1989

Prepared for:
U.S.Army Research Office
under CONTRACT NO. DAAL03-88-G-0070

School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

GITAER 89-2

THE VIEWS, OPINIONS, AND/OR FINDINGS CONTAINED IN THIS REPORT ARE THOSE OF THE AUTHOR AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION, POLICY, OR DECISION, UNLESS SO DESIGNATED BY OTHER DOCUMENTATION.

PREFACE

This work was supported by the Fluid Dynamics Program Office of the U.S. Army Research Office under the Defense University Research Instrumentation Program. The Army Technical Monitor was Dr. Thomas L. Doligalski. The Georgia Tech principal investigator was Dr. Narayanan M. Komerath.

FINAL REPORT: OCTOBER 1, 1988 TO SEPTEMBER 30, 1989

COPPER VAPOR PULSED LASER SYSTEM FOR PLANAR DIAGNOSTICS

STATEMENT OF THE PROBLEM

It is at present a major undertaking to measure the velocity field around complex aerodynamic configurations. For example, it takes an average of 7 minutes per measuring point to quantify the periodic velocity variation in the wake of a rotor blade using the laser Doppler velocimeter. This is a major hindrance to the development and validation of computational techniques for predicting complex flowfields, such as those around rotorcraft. It also makes detailed testing of rotorcraft models prohibitively expensive in wind tunnel resources. These problems have severe cost impacts on design improvements.

On a more fundamental level, the fluid dynamic phenomena in a multitude of very interesting flows are inaccessible to the researcher because of the difficulties in quantifying the velocity field. Approaches using point measurement techniques such as the laser Doppler velocimeter are practically hopeless in trying to understand turbulent phenomena in high-speed jets and mixing layers. In vortex cores, they present equally daunting problems. Thus, it is a current objective of fluid dynamics research to develop planar diagnostic techniques, where quantitative velocity information at several points in a cross-section of the flowfield are simultaneously obtained. Of course, three-dimensional techniques would be even more desirable, but are also further away in feasibility.

Several approaches are being taken towards this objective, by various researchers. The present author proposed, a couple of years ago, a method by which the measurement of velocity could be converted from a facility-intensive problem to one that was computationally intensive. The key element required to test this idea was a high-powered light source, which could be operated in very short pulses, but with a high repetition rate. The copper vapor laser was the ideal solution to this problem, since it operates in 25-nanosecond pulses, at repetition rates of 3000 to 8000 per second. Even though the velocity measurement idea entailed very high technical risk, being entirely new, it was argued that the copper vapor laser had many other vital applications in fluid mechanics research, ranging from excellent flow visualization capabilities to quantitative density and concentration measurements in some flows using Rayleigh scattering techniques. Thus, it was proposed as a versatile research tool.

The School of Aerospace Engineering at Georgia Institute of Technology, through the Georgia Tech Research Corporation, was awarded a one-year contract in September 1988 to purchase a copper vapor laser system under the Defense University Research Instrumentation Program. This report describes the status of this system at the end of the one-year contract.

STATUS REPORT AT THE END OF THE YEAR

The status of the system at the end of 7 months was communicated in a letter to the Technical Monitor. At that time, routine operation had already been achieved. Thus, the current status is different only in that more items that were on order have now been received, and more progress has been made on the research.

1. Equipment Purchase

The laser has been purchased and installed. An additional laser tube has been put on back order. Optics components for conditioning and delivery of the beam have been received and installed. Thus, all of the D.o.D.-funds for equipment purchase have been expended.

2. Operations

The copper vapor laser system is in routine use. It is currently operated on alternate days, for periods averaging about 3 hours. Since the system became operational in April '89, it has been operated for approximately 200 hours.

The laser system is relatively expensive to maintain. The laser consumes neon gas. The initial gas supply has been exhausted, and a second bottle acquired. These are projected to require replacement at the rate of about 4 bottles/ year in the future, at a cost of about $400 per bottle.

The optic fiber has failed twice to-date, and has been repaired at a cost of approximately $100 for each occurrence. These failures appear to be unavoidable, since any misalignment or stress on the fiber will result in the 20-30 watt beam burning through.

3. Research Performed to-date

The laser has been used for two projects. The first is in developing planar velocimetry as part of Aerodynamics Task 2 (Aerodynamic Interactions) of the Center of Excellence in Rotary Wing Aircraft Technology (CERWAT), and the second is in studying the behavior of the vortex system of a swept rotor tip at high pitch angles in hover using laser sheet videography under CERWAT Aerodynamics Task 3 (Blade Tip Aerodynamics).

Planar Velocimetry

High-speed motion pictures have been acquired of the longitudinal section of a seeded air jet. Initial attempts to perform the high-speed photography, with the laser phase-synchronized with the camera at 1000Hz, failed due to poor film exposure.The laser pulse intensity decreases at pulse rates below about 3000 per second. A subsequent high-speed motion picture run at 4500Hz also did not work, and it was concluded that the light collection system had to be improved. Such a system has been designed. A large lens assembly has been fabricated using old aircraft camera lenses salvaged from one of our store-rooms, and this is being calibrated. The objective is to set up a system that will allow the collection of light from a much larger solid angle than is possible with standard lenses, so that better light intensity can be achieved at the highest framing rates. Preliminary photographs have been developed, and the images appear to be of adequate quality while being quite undistorted. A large increase in light collection has been demonstrated, and photography at a shutter speed of 1/4000 second has been accomplished using the P.I.'s SLR camera. At present, this system is being modified to be compatible with the motion picture camera.

The jet was photographed at 500 frames per second, with the laser operating at 6000 pulses per second. This was a success, and the film clearly shows the motion of patterns of seeding in the jet. The motion near the jet axis is much greater in the axial direction from frame to frame than that near the edges. Near the edges, the roll-up of the patterns is clearly visible from one frame to the next. Several frames from this film have been transferred to videotape, and digitized.

Cross-correlations are now being constructed between image pairs digitized from this videotape, to determine velocity vectors at 16 points in each 640 x 480 digitized frame. Preliminary results are very encouraging, and excellent correlation plots have been observed for all cases studied to-date. This success suggests that the planar diagnostic technique may have far wider-ranging utility than was previously believed, and may directly open the way to planar velocimetry in non-periodic, fully turbulent, and high-speed flows.

Blade Tip Flow Visualization

The laser is now in routine use to study the vortex system of the advanced rotor tip which has been built under CERWAT Aerodynamics Task 3. This rotor tip has a planform similar to that of the BERP tip used on the Westland Lynx helicopter, and airfoil sections derived from the NACA 00xx family. It is attached to the NACA 0012 blade in the 9-foot Hover Facility. The surface co-ordinates for this blade tip were generated from the geometry used by Professor Sankar for Navier-Stokes computations. The initial experimental study is aimed at determining the behavior of the tip flowfield under hovering conditions at extreme blade pitch angles. The laser beam is conducted through an optic fiber into the facility, and expanded into a sheet which can be oriented as desired. Several different configurations have been tested. Using a pair of synchronous motors and a slotted disc, the laser beam has been strobed to freeze the vortex cross-sections at selected rotor azimuths. More recently, the motion of the vortex cores has been videotaped. As the blade pitch angle is increased above approximately 17 degrees, the concentrated tip vortex core is seen to disappear. However, a vortical flow pattern persists around the blade tip even at extreme pitch angles of 30 degrees.

The laser sheet was oriented to lie in a plane containing the rotor shaft axis and the rotot radius at a specified azimuth, on the inflow side, in order to check for the occurrence of leading-edge vortices on the inboard edge of the BERP tip. No clear vortex structure could be observed except for the tip vortex. This is so far in agreement with CFD predictions, which also fail to show any concentrated inboard vortex.

Some of the images of the tip vortex system, recorded on videotape, have been digitized using the Macintosh II-based image capture board (RasterOps Truecaptture® 324) purchased under Aerodynamics Task 2. Software development on this system (Philip Fawcett) has progressed to the point where we can now convert pixel color values into integers for image processing. As this effort progresses, we plan to test our planar velocimetry algorithm to track vortex core motion, and then to extend it to more complex patterns.

The utility of the laser for flow visualization may be illustrated qualitatively by the fact that previously, we had to place the videocamera in a forward scatter light collection mode to be able to see the vortex with a 5-watt Argon ion laser sheet. At present, the camera saturates whenever there is substantial seeding in the laser sheet, even when placed at 90 deg. to the light sheet. We have had to reduce the sensitivity of the camera. Thus, where previously we had to strobe the laser and study only periodic phenomena, we now can study detailed flow dynamics using continuous videography.

By separating the laser beam into its two dominant wavelengths, (510.6nm and 578nm), two laser sheets of distinctly different colors can be created. By placing these sheets in orthogonal planes, two cross-sections of a given flow structure can be observed and recorded simultaneously. The possibilities opened up by this technique are being investigated.

Two abstracts have been accepted by the SECTAM Conference (Atlanta, March 1990) on work being done with the Copper Vapor laser system. The BERP tip work also forms the initial part of the experimental study submitted as part of the abstract of a CFD/experiment paper to the AHS Forum. We have been informed that both have been accepted for presentation. are enclosed. The planar velocimetry work is being submitted to the AIAA Fluid Mechanics Conference (Seattle, June 1990).

LIST OF PARTICIPATING SCIENTIFIC PERSONNEL

1. Dr. Narayanan M. Komerath, Assistant Professor

2. Dr. Shiuh-Guang Liou, Post-Doctoral Fellow

3. Mr. Philip Fawcett, Graduate Research Assistant

4. Mr. Robert Funk, Undergraduate Student (performing Senior Special Problem Research)

LIST OF PUBLICATIONS

(Note: these publications were supported under other projects, but used the equipment discussed in this report)

1. Komerath, N.M., Liou, S-G., Fawcett, P.A., "Planar Velocimetry Using Digital Cross-Correlations". Accepted for presentation at the SECTAM Conference, March 1990.
2. Liou, S-G., Fawcett, P.A., Komerath, N.M., "Flowfield Measurements Near the Tip of a Rotor Blade Near Stall". Accepted for presentation at the SECTAM Conference, Atlanta, March 1990.
3. Tsung, F.-L., Liou, S.-G., Sankar, N.L., and Komerath, N.M., "Computation and Measurement of the Flowfield Near a Swept Rotor Blade Tip in Hover". Abstract submitted to the 46th Annual Forum of the American Helicopter Society.
4. Komerath, N.M., Fawcett, P.A., "Planar Velocimetry By Spatial Cross-Correlation: Theoretical Basis and Validation". Abstract submitted to the AIAA 21st Fluid Dynamics, Plasmadynamics, and Lasers Conference, Seattle, WA 1990.

INVENTION DISCLOSURES

1. Komerath, N.M., "Planar Cross-Correlating Velocimeter". Invention Disclosure filed with Georgia Institute of Technology, Office of Technology Transfer, November 1989.

(Note: this invention was supported under other projects, but used the equipment discussed in this report)